REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

AD-A244 885

2. REPORT DATE: December 1991

3. REPORT TYPE AND DATES COVERED: professional paper

4. TITLE AND SUBTITLE: ADVANCED TETHERED VEHICLE

5. FUNDING NUMBERS:
PR: MS09
PE: 0603713N
WU: DN188508

6. AUTHOR(S): W. S. Morinaga and R. T. Hoffman

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES):
Naval Ocean Systems Center
San Diego, CA 92152-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES):
Naval Sea Systems Command
Program Executive Office
Washington, DC 20362

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT: Approved for public release; distrib..tion is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The Advanced Tethered Vehicle (ATV) is a self-contained, remotely operated submersible system designed to carry out Navy work missions at ocean depths to 20,000 feet. It consists of a submersible vehicle, tether cable, handling system, control station, and auxiliary equipment. The vehicle is positively buoyant and carries two force feedback manipulators and interchangeable tools for performing work. The system has completed a rigorous test program that accumulated 248 operating hours and concluded with a successful dive to 20,600 feet.

92 1 22 080

92-01846

Published in *Oceans '91*, Vol. 3, 1991.

14. SUBJECT TERMS:
CIVAPP
deep ocean technology
deep recovery
submersible vehicles

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAME AS REPORT

UNCLASSIFIED

21a. NAME OF RESPONSIBLE INDIVIDUAL	21b. TELEPHONE *(include Area Code)*	21c. OFFICE SYMBOL
W. S. Morinaga	(619) 553-5289	Code 534

NSN 7540-01-280-5500

Standard form 298

UNCLASSIFIED

ADVANCED TETHERED VEHICLE

Wayne S. Morinaga and Robert T. Hoffman

Naval Ocean Systems Center, Hawaii Laboratory
P.O. Box 997
Kailua, HI 96734-0997

ABSTRACT

The Advanced Tethered Vehicle (ATV) is a self-contained, remotely operated submersible system designed to carry out Navy work missions at ocean depths to 20,000 feet. It consists of a submersible vehicle, tether cable, handling system, control station, and auxiliary equipment. The vehicle is positively buoyant and carries two force feedback manipulators and interchangeable tools for performing work. The system has completed a rigorous test program that accumulated 248 operating hours and concluded with a successful dive to 20,600 feet.

BACKGROUND

The Naval Ocean Systems Center (NOSC) has been developing remotely operated vehicle (ROV) systems since 1965, continually improving capabilities as technology has evolved. NOSC experience includes the development of the Cable-controlled Underwater Recovery Vehicle (CURV), the Remote Unmanned Work System (RUWS), the Mine Neutralization Vehicle, and the Work System Package (WSP). When combined with in-house technology development in fiber optics and digital telemetry, this background permitted NOSC to confidently produce a Fleet operable system with 20,000 ft capability: An Advanced Tethered Vehicle (ATV).

REQUIREMENTS

ATV is a complete system, independent of the support ship, built to Navy requirements which include a maximum attainable depth of 20,000 feet, a forward speed of 2 kn, operation in sea state 3, mean time between critical failures of 240 hours, and a mean time for shipboard repairs of 6 hours. Included with the hardware are all the necessary documentation to operate, maintain and logistically support the system in the Fleet.

SYSTEM CONCEPT DEVELOPMENT

To minimize system complexity, the concept of a buoyant vehicle with a continuous cable between the ship and the vehicle was chosen. The transmission of two simultaneous video signals and the requirement for a small tether cable diameter, led to the selection of optical fibers as the communication medium. In addition to the development of an optical telemetry link with its associated cable, careful attention was paid to the general problem of launch/recovery of the vehicle. The remainder of the system could be designed based on prior experience, avoiding previously encountered problems and incorporating features to simplify operation and maintenance and to improve reliability. Such features include: (1) two identical manipulators, (2) two identical vehicle motor/pump units, (3) isolated tool hydraulics, (4)

doubly redundant vehicle electro-optics, (5) redundant vehicle lift capability, (6) redundant motor/pumps in the deck power unit, (7) redundant cable traction drive motors, (8) separate vehicle lift line, (9) ram tensioner, and (10) redundant system power supply

The ATV concept is shown in Figure 1. The system consists of a buoyant vehicle, a tether cable, a control van and a surface handling system. Two unique features set this system apart. The first is that the vehicle is launched and recovered using a steel lift line separate from the tether cable and is towed by the ship while floats are attached to the cable adjacent to the vehicle. This approach greatly reduces stresses on the vehicle cable termination and allows a less strength-efficient but faster cable retermination process. It also permits the vehicle to be handled with power off and enables a totally reversible launch/recovery procedure. The second feature is a ram tensioner for the lift line. This eliminates lift line snap loads during launch/recovery of the vehicle and also permits the tether cable to be supported by the lift line during deep operation to reduce dynamic loading (reference 1).

SYSTEM DESCRIPTION

Vehicle

The vehicle is 198 inches long by 115 inches wide and 84 inches high. Its air weight is 13,000 pounds; in-water buoyancy is between 50 and 150 pounds. The vehicle frame is constructed from standard aluminum alloy 5086 shapes. Syntactic foam modules are mounted on the top and titanium pressure housings containing electrical and optical components are located on the bottom level of the vehicle. A television camera and sonar used in maneuvering to the target, are mounted behind the front fairing. The tether cable is attached to a boom at the front of the vehicle. The boom is pivoted to allow the cable to exit the vehicle horizontally during surface handling (Figure 2) and vertically during submerged operation. The work package is mounted on the aft end.

A hydraulic system consisting of dual, variable displacement pumps, operates at 3000 psi providing up to 26 gpm of oil to the five thrusters, manipulators, pan and tilt units, and the tool package motor. Sensors used to monitor the hydraulic systems include pressure transducers, thermistors, flow sensors and potentiometers to sense oil compensation levels. A switch on the main vehicle hydraulic system compensator shuts down the pumps if the compensator level drops below 25%. This automatic shutdown can be manually overridden if necessary.

The work package consists of two manipulators, four television cameras, a 35 mm photographic camera and strobe, and a variety of tools and lights. The manipulators are identical master/slave units with force feedback. Each manipulator has 7 degrees of freedom and can lift 65 pounds at full extension. The two manipulators are configured to replicate the left and right arms of the operator.

Two of the four TV cameras are used as a stereo pair, another has zoom capability, and the fourth acts as a viewfinder for the photographic camera and provides a fixed view of the work area. The stereo pair cameras and the zoom

camera are mounted on pan and tilt units. The zoom TV camera has a 6:1 zoom capability. All four cameras are black and white.

The tools are mounted on a support tray below the manipulators. They include a rotary drive to which an abrasive cutoff wheel, drill, or impact wrench can be attached, and independent linear tools consisting of a spreader, cable cutter, jack and grabber. The linear tools are standard surface units which have been modified slightly for underwater use. A servo valve controls the rotary tools and a solenoid controlled pressure intensifier drives the linear tools.

Besides TV cameras and hydraulic sensors, the ATV system incorporates a variety of sensors to enhance operations. A long baseline navigation system is used to determine the vehicle and ship's positions. The vehicle normally operates in the responder mode, but in an emergency situation it can also operate in the transponder mode. A pulse scan sonar is used as a forward looking sonar and it can also be tilted vertically to provide altitude information. An altitude sonar with a range of 500 feet determines the vehicle's distance from the ocean floor. A quartz pressure transducer provides vehicle depth information. A fluxgate compass determines the vehicle heading. Sea water leak detectors are located in the major electrical housings and tachometers monitor the thrusters rotation.

Cable

The 23,000 ft long tether cable is the principal developmental item in the system. It incorporates three power conductors, three multi-mode optical fibers, a Kevlar strength member, and an outer yellow jacket with a black stripe. The black stripe is used to monitor cable rotation. The cable cross-section is shown in Figure 3 and its characteristics are listed in Table I.

Power

Figure 4 is the overall block diagram of the ATV electrical power distribution. To meet the requirement that it be self-contained and be able to operate on ships of opportunity, the ATV system includes two diesel generators that provide power for the entire system. Each generator provides 480 volts, 60 Hz, 3-phase power at a capacity of 180 kw. During normal operations, one generator powers the control van and the vehicle and the other powers the surface handling system. If one generator fails, the other generator is able to power the entire system.

In the control van, a 30 KVA transformer steps down the 480 volts to 208 and 120 volts. These voltages power the electronic circuits and equipment in the van and also the utilities such as the air conditioners and lights. The van has two air conditioner/heater units for redundancy. Also, in the control van is the high voltage console which has a 100 KVA transformer that steps up the 480 volts, 3-phase input to 2400 volts. This 2400 volt, 3-phase power is then transmitted to the tether cable via slip rings. The high voltage console includes over current trip and ground fault interruption circuits to protect personnel and equipment.

At the vehicle, the 2400 volt, 3-phase power goes to motor switching circuits that control two

25 HP electrohydraulic units. The motor switching circuits were designed and assembled by the David Taylor Research Center. These switching circuits use rugged, heavy duty, reliable vacuum contactors. Each motor circuit is separately fused and overload current protected. The two electrohydraulic units and their individual motor control circuits provide redundancy in the hydraulic system.

The vehicle also has a five kilowatt transformer that steps down the 2400 volts to lower voltages that power the electronic circuits, equipment, and lights. Each low voltage winding circuit is fused to protect the transformer.

Telemetry

The ATV fiber optic telemetry subsystem utilizes wavelength division multiplexing to provide full duplex communications over a single optical fiber. The downlink optical wavelength is 1.55 microns, while the uplink optical wavelength is 1.3 microns. Dichroic filter wavelength division multiplexers separate and integrate the two wavelengths. Commands are transmitted from the surface to the vehicle on the downlink telemetry channel at a 2.5 MBPS data rate. The vehicle instrumentation data, sonar signal, and two realtime video signals are transmitted from the vehicle to the surface on the uplink telemetry channel at a rate of 200 MBPS.

Figure 5 shows the physical configuration of the telemetry subsystem. The surface telemetry circuits are installed in the control van. An optical fiber connects the telemetry circuits to the optical slip ring located in the center of the tether storage reel. Assembled with the optical slip ring are optical switches that couple the optical slip ring to any one of the three fibers in the tether cable. At the vehicle, each of the three fibers is connected to individual electro-optical transmitter and receiver circuits.

Because only one fiber is required for the full duplex communications, there is dual redundancy of fibers and the electro-optical circuits on the vehicle. Any optical fiber can be selected with the system online. This redundancy increases the system reliability and has proven very beneficial during operations.

Control Station

The control station is located in the control van which is 8'W X 20'L X 8'H. Figure 6 is the layout of the control van. The vehicle operator and the work operator are stationed at the control console. This console contains the controls and displays for operating the vehicle and the work package. A computer graphics display that integrates realtime video with graphics is positioned before the vehicle operator to minimize the operator's required viewing area. The work operator station includes the two force feedback manipulator masters and the controls for operating the work suite. The tether operator is stationed at the tether control console which contains the controls and displays for operating the tether. The high voltage console has the controls for switching on the high voltage and the displays for monitoring the power. For personnel safety, it is located away from the operators and the exit.

The control station was designed to facilitate maintenance. The

rear of the control console is accessible and also the console hardware was designed for accessing the circuits from the rear of the control console. This makes the circuits easily available for online monitoring or troubleshooting.

SYSTEM OPERATION

System operation begins with a deck checkout of all subsystems. The vehicle is then launched and towed at slow speed while floats are attached to the tether cable near the vehicle. The vehicle is then powered up and driven to the sea floor as the tether is reeled out. Once on the sea floor, the vehicle is maneuvered to the previously located target using a combination of navigation data, forward looking sonar, and television. Once the target is located, the vehicle rotates to enable the operator to use the manipulators, tools, and/or documentation cameras. Following work task completion, the vehicle is recovered by thrusting to the surface and reeling in the tether. Rinsing down the vehicle and a final deck checkout completes the mission.

All vision system options have proven to be useful, particularly the zoom camera. Manipulator operation is exceptional, capable of capturing swimming or crawling creatures, as well as tying knots and recovering small items from the sea floor. The tools have been used to cut cables and angle iron, remove nuts, and slit and pry apart aluminum sheet. Manipulator operation has been easy to learn, with novices performing actual tasks as part of their training.

REFERENCES

1. Yumori, I.R., Advanced Tethered Vehicle Surface Handling System Test, NOSC TR 1273, December 1988

Table I - Cable Characteristics

DC Resistance	9.35	ohms/23 kft
Insulation Resistance	1,500	megohms/23 kft
Optical Attenuation @ 1.3 um		
No Load	0.6	dB/km
10,000 psi ambient pressure	0.8	dB/km
10,000 lb tension	0.7	dB/km
Safety Factor based on in-water wt.	7.5/8.4*	
Cable Torque	+2/-147*	in-lb
Cable Rotation	0/-1.3*	deg/ft

* measured on samples from both ends

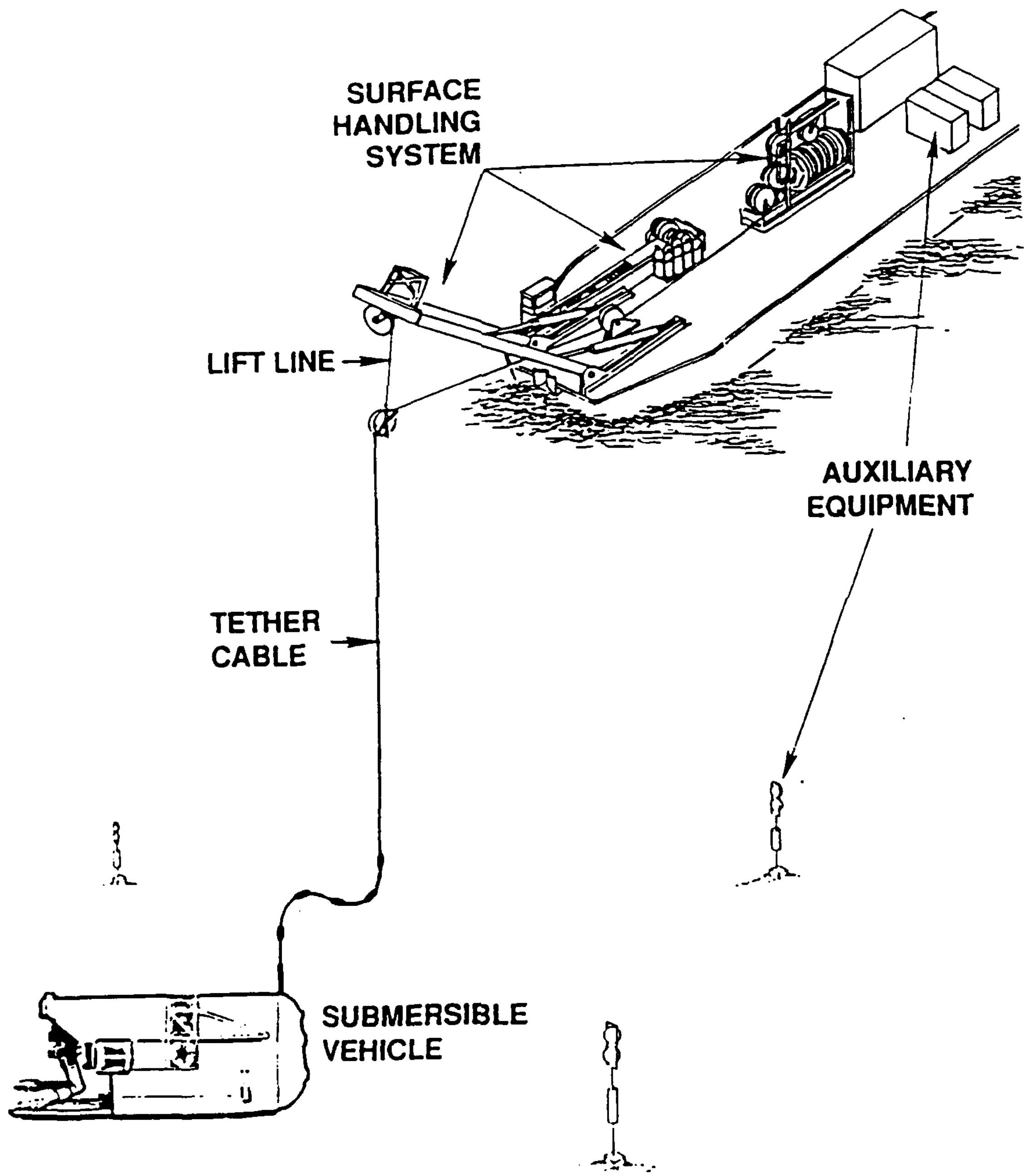

Figure 1. ATV System concept.

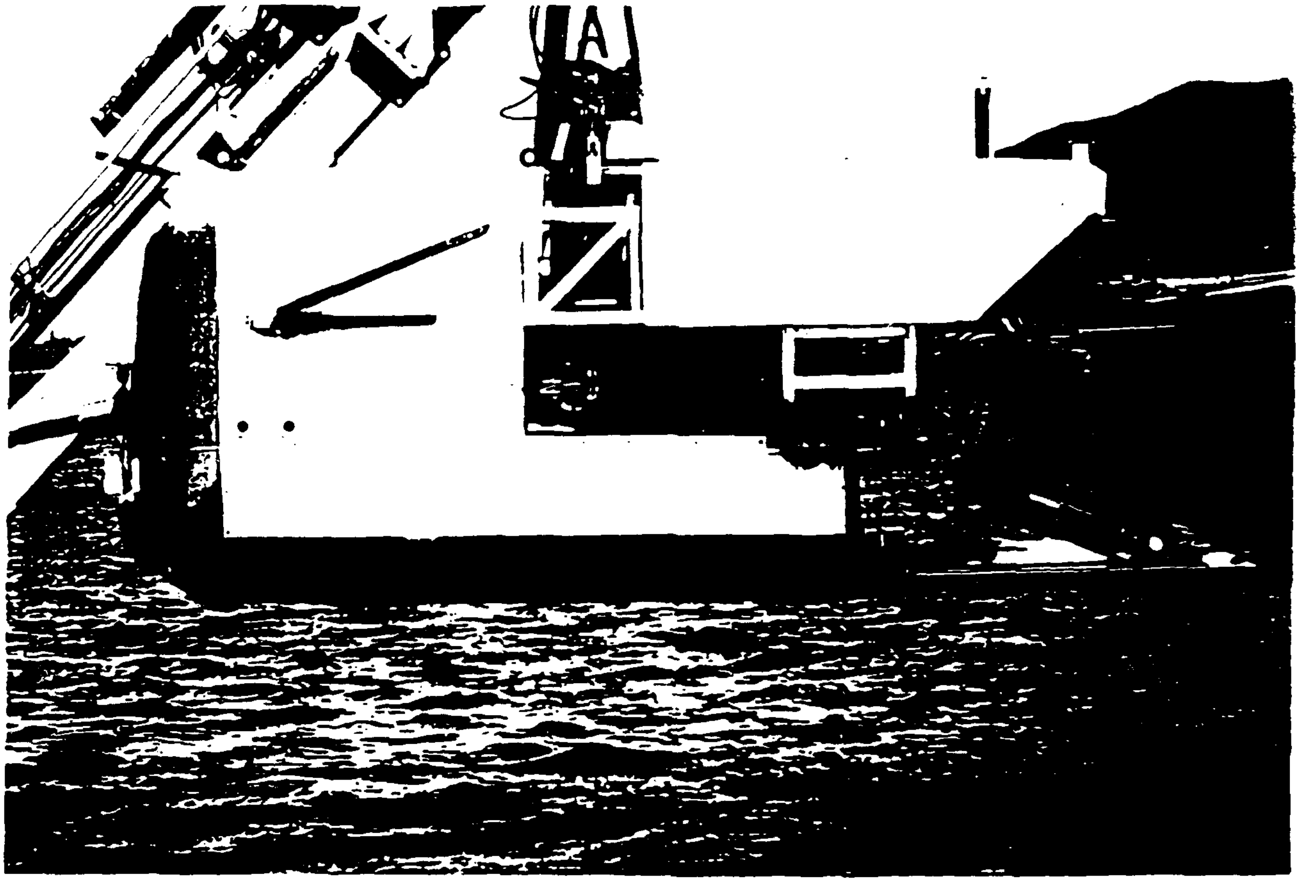

Figure 2. ATV Vehicle.

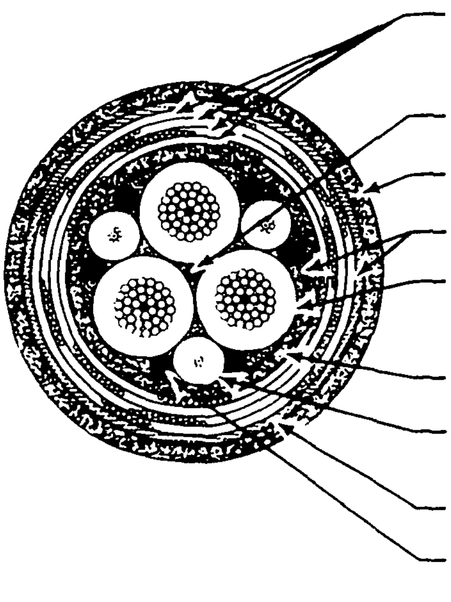

Figure 3. Cable cross section.

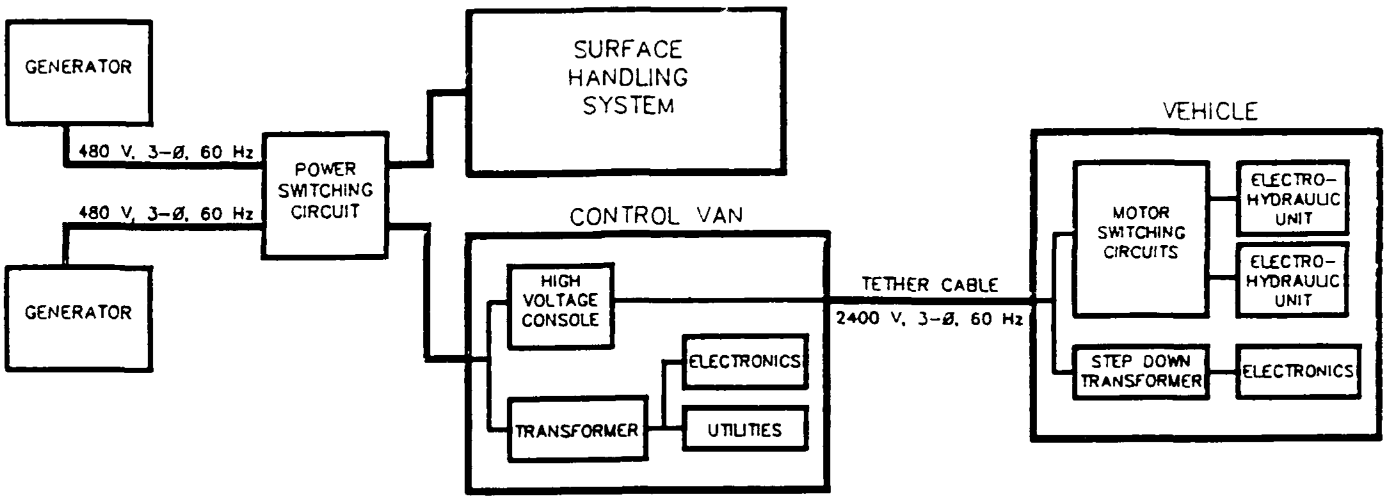

Figure 4. Power distribution block diagram

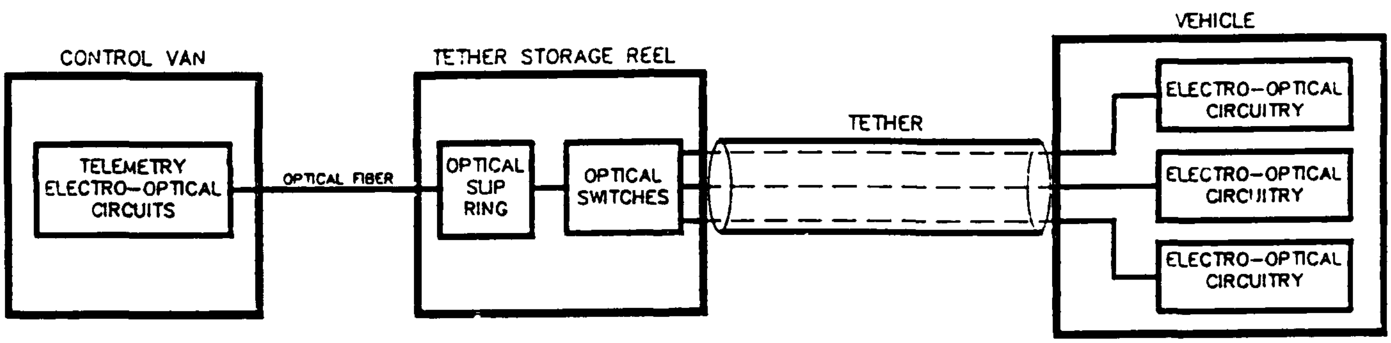

Figure 5. Fiber optic telemetry configuration

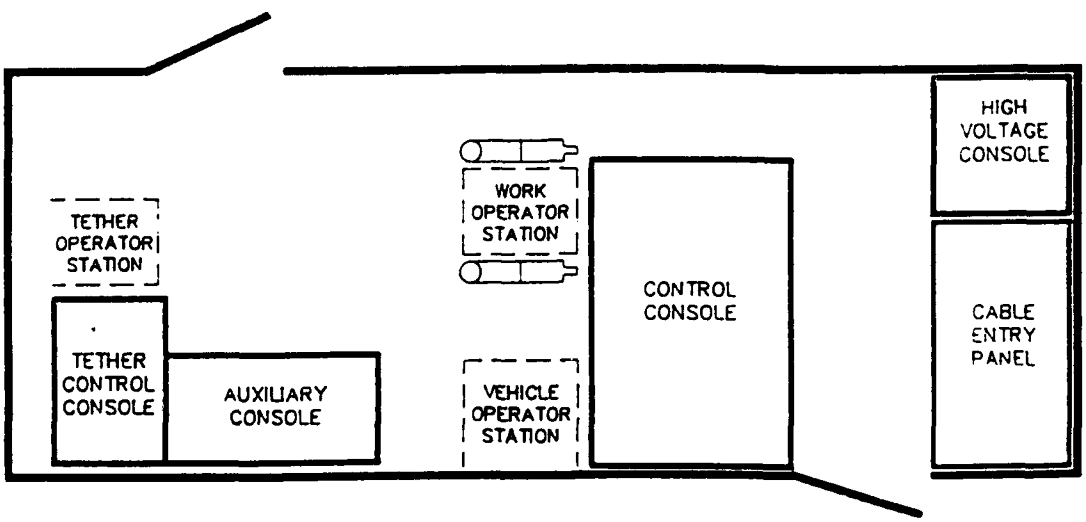

Figure 6. Control van layout